I. C. 6765

APRIL, 1934

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

WYOMING COAL-MINE EXPLOSIONS, 1881 - 1931

BY

G. M. KINTZ

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WYOMING COAL-MINE EXPLOSIONS - 1881 TO 1931[1]/

By G. M. Kintz[2]/

The data in this circular were taken from publications of the United States Bureau of Mines and published annual reports of the Wyoming State Inspector of Coal Mines. The tables included are complete only with regard to major disasters; the Bureau of Mines considers a major disaster one in which 5 or more men are killed. However, minor disasters and gas ignitions recorded in these publications are included. It is known that a number of gas ignitions have occurred of which no record is available.

This is one of a series of papers by the Bureau of Mines giving by States available data regarding coal-mine explosions. This information is published in condensed form in the belief that it may be of value to mine operators in preventing future coal-mine explosions.

Explosions and gas ignitions.- Tables 1 and 2 give available data on number killed and injured, the cause and possible means of prevention at the time of 68 explosions and gas ignitions that occurred in Wyoming from 1881 to 1931, inclusive.

TABLE 1. - Wyoming coal-mine explosion data, 1881 - 1931

Year	No. of explosions of gas ignitions	No. killed	No. injured	Year	No. of explosions or gas ignitions	No. killed	No. injured
1881	1	38		1918	4		5
1886	1	13		1919	3	2	2
1895	1	60		1920	7		10
1901	1	22		1921	6		8
1903	1	169		1922	10		16
1905	1	18		1923	12	99	12
1907	1	1	31	1924	2	39	1
1908	1	59		1926	2	2	1
1911	2	1		1927	2	1	4
1912	1	7		1929	1		1
1917	5		7	1931	3		5
Total, 1881 - 1931					68	531	103

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6765."

2/ Associate mining engineer, U. S. Bureau of Mines, Denver, Colo.

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
1	3/4/1881	Uintah	Slope	-	-	-	-	-	-	-	-	38	-	-
2	1/13/1886	do	do	-	-	-	-	-	-	-	-	13	-	-
3	3/20/1895	do	do	-	65	60	-	-	-	-	Gas and dust	60	-	-
4	10/26/1901	Lincoln	do	-	-	-	-	Said to be gas. Short circuit of air while fighting mine fire.	Said to be mine fire.	-	Gas	22	-	-
5	6/30/1903	Carbon	do	-	-	-	-	-	Blown-out shot.	-	Gas and dust	169	-	-
6	12/1/1905	Lincoln	do	-	-	-	-	-	-	-	-	18	-	-
7	1907	Sweetwater.	do	-	-	32	Localized	Runaway trip down slope wrecked raising cloud of dust.	Open lights.	Sprinkling of trip and use of derailing device.	Dust	1/	31	-
8	3/8/1908	Carbon	do	-	-	59	Entire mine	-	Mine fire.	-	Gas and dust	59	-	-
9	1/27/1911	Sheridan	Drift	312,094	285	-	-	Gases distilled by mine fire.	Mine fire due to spontaneous combustion.	Better system of development.	Gas and dust	0	0	0

1/ Died later as a result of injuries received.

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Continued

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
10	5/27/1911	Lincoln	Slope	293,355	282	-	-	Unknown.	Gas watchman relighting his lamp.	-	Gas	1	-	-
11	1/20/1912	do	do	146,281	-	-	-	Dust cloud raised by shots.	Blown-out shot	Better location of holes, permissible explosives	Dust	7	-	-
12	3/23/1917	do	do	-	-	-	-	-	Lighted gas. Cause not given.	-	Gas	0	2	-
13	4/10/1917	do	do	-	-	-	-	-	do	-	do	0	1	-
14	4/15/1917	do	do	-	-	-	-	-	Lighted gas in a hole. Cause not given.	-	do	0	1	-
15	5/28/1917	do	do	-	-	-	-	-	Lighted gas. Cause not given.	-	do	0	2	-
16	9/9/1917	do	do	-	-	-	-	-	do	-	do	0	1	-
17	7/22/1918	Uintah	do	51,147	44	31	-	-	Explosion of gas. Cause not given.	-	do	0	2	-

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Continued

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
18	7/29/1918	Sheridan	Slope	326,931 2/	229 2/	178 2/	-	-	Explosion of gas. Cause not given.	-	Gas	0	1	-
19	8/23/1918	Lincoln	do	-	-	-	-	-	Lighted gas. Cause not given.	-	do	0	1	-
20	10/1/1918	do	do	199,340	-	-	-	-	Ignition of gas. Cause not given.	-	do	0	1	-
21	1/24/1919	do	-	140,270	-	-	-	-	do	-	do	0	1	-
22	6/3/1919	Sheridan	Shaft	185,754	94	7	Localized	Door left open, short-circuiting air.	Unknown.	Positive ventilation.	Gas and dust	2	0	5
23	6/7/1919	Lincoln	Slope	140,270	-	-	-	-	Ignition of gas. Cause not given.	-	Gas	0	1	-
24	3/26/1920	do	do	171,668	-	-	Localized	Pocket of gas.	Cause not given.	-	do	0	1	-
25	4/5/1920	do	do	209,301	-	-	do	-	do	-	do	0	1	-
26	6/29/1920	do	do	209,301	-	-	do	-	do	-	do	0	1	-
27	7/9/1920	Sheridan	Shaft	250,639	213	-	do	Pocket of	do	-	do	0	1	-
28	8/10/1920	Lincoln	Slope	160,451	-	-	do	-	-	-	do	0	1	-
29	12/18/1920	do	do	171,668	-	-	do	-	Coal-dust flame. Cause not given.	-	Dust	0	4	-
30	12/24/1920	do	do	25,149	-	-	-	-	do	-	do	0	1	-

2/ Includes two mines.

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Continued

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
31	2/11/1921	Lincoln	Slope	197,410	-	-	Localized	-	Cause not given.	-	Gas	0	2	-
32	6/18/1921	do	do	197,410	-	-	do	-	do	-	do	0	1	-
33	8/23/1921	do	do	81,423	-	-	do	-	Ignition of gas. Cause not given.	-	do	0	1	-
34	9/26/1921	Lincoln	do	256,107	-	-	do	-	do	-	do	0	1	-
35	10/18/1921	Sweetwater	do	69,960	-	-	do	-	do	-	do	0	2	-
36	11/8/1921	Lincoln	do	197,410	-	-	do	-	do	-	do	0	1	-
37	1/27/1922	do	do	188,931	-	-	do	-	do	-	do	0	1	-
38	1/30/1922	do	do	115,717	-	-	do	-	do	-	do	0	5	-
39	8/14/1922	Sweetwater	do	70,961	-	-	do	-	do	-	do	0	1	-
40	9/6/1922	Lincoln	do	188,931	-	-	do	-	do	-	do	0	1	-
41	9/13/1922	do	do	115,717	-	-	do	-	do	-	do	0	1	-
42	10/12/1922	do	do	115,717	-	-	do	-	do	-	do	0	1	-
43	11/5/1922	Carbon	do	250,087	-	-	do	Pocket of gas in high place.	Open light.	Better inspection by fire boss.	do	0	1	-
44	11/28/1922	Sheridan	do	88,688	207	-	do	Struck pocket of gas, igniting it.	do		do	0	2	-
45	12/20/1922	Lincoln	do	115,717	-	-	do	-	Ignition of gas. Cause not given.	-	do	0	1	-

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Continued

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
46	12/21/1922	Lincoln	Slope	188,931	-	-	Localized	Pocket of gas.	Ignition of gas. Cause not given.	-	Gas	0	2	-
47	1/18/1923	do	do	163,549	-	-	-	-	do	-	do	0	1	-
48	1/30/1923	do	do	163,549	-	-	-	-	do	-	do	0	1	-
49	2/18/1923	do	do	163,549	-	-	-	-	do	-	do	0	1	-
50	2/24/1923	do	do	178,863	-	-	-	-	do	-	do	0	1	-
51	5/12/1923	do	do	163,549	-	-	-	-	do	-	do	0	1	-
52	7/7/1923	do	do	163,549	-	-	-	-	do	-	do	0	1	-
53	7/19/1923	do	do	178,863	-	-	-	-	do	-	do	0	1	-
54	7/21/1923	do	do	163,549	-	-	-	-	do	-	do	0	2	-
55	8/14/1923	do	do	201,258	-	135	Entire mine, not violent	Uncertain; probably line brattice deranged by a fall.	Fire boss attempting to relight flame safety lamp in presence of gas.	Use of magnetically-locked flame safety lamp, rock-dust; better ventilation.	Gas and dust	99	0	36
56	9/25/1923	Sweetwater	do	98,584 1/	-	-	-	-	Ignition of gas. Cause not given.	-	Gas	0	1	-
57	9/27/1923	Lincoln	do	163,549	-	-	-	-	do	-	do	0	1	-
58	10/6/1923	do	do	178,863	-	-	-	-	do	-	do	0	1	-
59	3/10/1924	Campbell	Shaft	19,263	50	-	Localized	-	-	-	do	0	1	-

1/ Includes production of two mines.

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Continued

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
60	9/16/1924	Lincoln	Slope	124,994	-	-	Entire mine	Leaky stoppings and brattices.	Electric arc.	Increased ventilation; tight stoppings; better installation of line brattice.	Gas and dust	39	0	12
61	6/9/1926	Fremont	do	76,456	89	-	Localized	-	Ignition of gas. Cause not given.	-	Gas	0	1	-
62	6/26/1926	Uintah	do	-	-	2	Entire mine	Shot of black blasting powder raised dust cloud.	Blown-out shot.	-	Dust	2/	0	-
63	6/9/1927	Lincoln	do	83,508	92	20	Localized	Open "slant" door short-circuited the air.	Arc from trolley.	Permissible storage-battery locomotives.	Gas	1	3	-
64	10/22/1927	Hot Springs	do	87,382	125	-	-	-	Unknown.	-	do	0	1	-
65	4/23/1929	Sweetwater	do	107,622	97	2	Localized	Feeder opened by shot.	Open light.	Permissible lamps.	do	0	1	-

2/ Includes 1 visitor.

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TABLE 2. - Explosions and gas ignitions in Wyoming coal mines, 1881 - 1931--Concluded

Case	Date	County	Type of opening	Production, tons per year	No. employed	No. in mine	Extent of explosion	Cause of presence of explosive atmosphere	Probable source of ignition	Possible means of prevention at time	Gas or dust explosion	No. killed	No. injured	No. escaped uninjured
66	5/26/1931	Lincoln	Slope	90,719	85	2	Localized	Pocket near roof.	Electric arc from nonpermissible electric drill.	Better ventilation; permissible electric drill.	Gas	0	2	-
67	6/24/1931	do	do	90,719	85	7	do	Brattice down.	Electric arc from nonpermissible mining machine.	Better care of ventilation.	do	0	2	-
68	10/12/1931	Uintah	do	12,462	22	20	do	Came from crevice. Old workings being reopened.	Open light.	Closed lights.	do	0	1	-

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Nature of explosions.- Approximately 72 percent of the men killed in the explosions listed in this paper lost their lives in the 8 explosions that occurred before 1910. The nature of the explosions with reference to gas and coal dust is shown in table 3:

TABLE 3. - Nature of explosions, with reference to gas or coal dust

Nature of explosion	No. of explosions	No. killed	No. injured
Unknown	3	69	0
Gas	53	24	67
Dust	5	10	36
Gas and dust	7	428	0
Total	68	531	103

In the 53 listed gas explosions 24 persons were killed and 67 injured. In the 5 listed dust explosions 10 men were killed and 36 injured. In the 7 listed gas and dust explosions 428 men were killed.

These figures illustrate that where a combination gas and dust explosion occurs the destruction of life and property is likely to be much greater than where gas alone is the exploding medium. They show the necessity of thorough rock-dusting and sprinkling of the working places, and of trips where possible, to prevent the participation of coal dust in explosions in bituminous and subbituminous mines. A study of widespread coal-mine explosions in the United States shows that almost invariably they involved either dust or both gas and dust.

TABLE 4. - Sources of ignition

Cause	No. of explosions	No. killed	No. injured
Unknown (no record)	51	131	60
Open lights	5	1	36
Relighting flame safety lamp	2	100	-
Mine fires	2	81	-
Spontaneous combustion	1	0	-
Electric arc	4	40	7
Blown-out shot	3	178	-
Total	68	531	103

Open lights.- Probably most of the explosions listed as unknown were caused by the use of open-flame lights, although the records are not clear on this point.

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Many persons have expressed the opinion that it is safe to use open lights in so-called nongassy mines and that there is only slight chance of ignition of a dust cloud thereby. Case 7 illustrates the fallacy of this opinion. Here the last trip of the shift broke loose from the tipple, ran down the slope, and was wrecked near a point where 32 miners wearing open lights were waiting for the man trip. The dust raised by this wrecked trip was ignited by the miners' open lights, killing 1 and injuring many of the others. Had the mine not been relatively clean at this place, the violence of the explosion probably would have been sufficient to kill all the men. The United States Bureau of Mines recommends (see Mine Safety Board Decision 1 and discussion thereof in this paper) portable closed lights of permissible type in all coal mines, not only from the hazard of dust ignition, as illustrated by this example, but also because of the gas-ignition and fire hazard of the open flame lamp.

In view of past experience with the ignition of explosive gas by open flame lamps and the demonstrated practicability, relatively good illumination, and cheapness of the electric lamp it is hard to understand why many coal-mine operators still permit the use of open lights in their mines.

Flame safety lamps.- In all, 100 men were killed in two explosions because flame safety lamps were taken apart and relighted in the presence of an explosive atmosphere. In both cases the men who committed this act probably knew better, but the human element in accident-prevention work frequently cannot be controlled; therefore, mine equipment should be as nearly "fool proof" as possible. The present up-to-date permissible flame safety lamp is magnetically locked and cannot be opened except by the use of a rather powerful, large magnet. The United States Bureau of Mines has no record that a properly assembled and properly maintained flame safety lamp ever caused an explosion, although numerous gas ignitions have been caused in coal mines both in the United States and in other countries when flame safety lamps have been mishandled; hence the flame safety lamp is by no means "fool proof". With these facts in mind, it is clear why the Bureau of Mines recommends the permissible magnetically-locked flame safety lamp; if this lock is kept in proper working condition and if the magnet is available only outside of the mine there will be little likelihood that a man will open his light underground.

Spontaneous combustion.- Some of the coal mines in Wyoming are subject to spontaneous combustion. The explosion listed as case 9 was caused by a fire started by spontaneous combustion. The fact that no one was killed or injured in this explosion was due to the good judgment of the mine foreman, who withdrew every man from the mine just a few minutes before the explosion occurred. The prevention as well as the successful control of mine fires, especially those due to spontaneous combustion, depends in great part upon the proper development and operation, and especially the cleanliness of the mine.

Mine fires.- During the fighting of mine fires in "soft" coal mines there is always a great gas-ignition hazard; those fighting such fires

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should fully realize this and take all possible precautions to protect themselves. If the area of the mine adjacent to the fire is given an extra heavy coating of rock-dust and the rest of the mine is properly rock-dusted, an explosion caused by the accumulation of gases by the mine fire probably will be localized enough to prevent much, if any, loss of life or damage to property.

Electric arc.- The coal mines of Wyoming probably have installed more electrical mining devices proportionately than in any other State in the Union. The increased installation of electrically operated mining machinery has greatly increased the explosion hazard from the ignition by an electric arc of an explosive mixture of gas, dust, or other combustible matter. Many types of permissible coal-mining machinery are available and should be used; it must be remembered, however, that a machine is permissible only as long as it is maintained and operated according to the instructions of the manufacturer and of the United States Bureau of Mines. In general, these instructions will be found on the permissible plate on every permissible machine or piece of equipment. Permissible electrical equipment maintained in permissible condition will greatly reduce the hazard of gas ignitions in places in mines that may become gassy. The Mine Safety Board of the United States Bureau of Mines makes the following recommendation regarding electricity in coal mines in decision 13[3/]:

> The United States Bureau of Mines recommends that when electricity is used in coal mines rated as gassy, or whenever in any mine the atmosphere may become gassy:
>
> 1. Electrical equipment shall be permissible.
>
> 2. Nonpermissible electrical equipment shall be used only in pure intake air.
>
> 3. Electrical power shall be cut off whenever the air in the workings is in a dangerous condition, due to inflammable gas.

Operators and mine electricians will find valuable information regarding electricity in mines in United States Bureau of Mines Technical Paper 402, Safety Rules for Installing and Using Electrical Equipment in Coal Mines.

Blown-out shots.- The use of black blasting powder and dynamite or the improper use of permissible explosives caused at least 3 explosions which resulted in the death of 178 men, approximately one third of all the men killed in the explosions listed in this paper. The poor placement of drill holes, too heavy charges of explosives, insufficient or improper tamping of holes, and blasting off the solid were some of the reasons for blown-out shots.

3/ United States Bureau of Mines, Mine Safety Board Decision 13; Recommendations of the U. S. Bureau of Mines on Certain Questions of Safety: Inf. Circ. 6732, July 1933, p. 22.

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TABLE 5. - Causes of gas accumulations or coal-dust clouds

Cause	No. of explosions	No. killed	No. injured
Short-circuiting of air, including leaky stoppings and deranged brattices down	6	163	5
Pocket of gas	6		8
Gases distilled by mine fires	1	0	
Feeder opened by shot	1	0	1
Gas from old workings	1	0	1
Dust raised by shots	2	9	
Dust cloud raised by wrecked trip	1	1	31
Unknown	50	358	57
Total	68	531	103

The explosives now designated as "permissible" were used first in 1907; since that time explosives manufacturers have from time to time improved them until now it is possible to obtain permissible explosives that will give virtually the same blasting results as black blasting powder. Explosives engineers have proved that the production of lump coal does not depend wholly upon the speed of detonation of an explosive; strength and density as well as other factors are also important. A good method of determining the proper explosive to use in blasting any coal is to consult the explosives manufacturers, who have explosives engineers well qualified to recommend the proper grade of permissible explosive.

If permissible explosives are not used according to the methods prescribed by the Bureau of Mines and the explosives manufacturers they may ignite an explosive mixture of gas or a coal-dust cloud; even though the explosive is properly manufactured and approved by the Bureau of Mines, it is not permissible if used in any of the following ways:

1. If stored under improper conditions until it undergoes a change in character.

2. If used in a frozen or partly frozen condition.

3. If used in excess of 1½ pounds per shot.

4. If the diameter of the cartridge is less than that designated in the column "smallest permissible diameter".

5. If fired with an electric detonator of less efficiency than that prescribed.

6. If fired with fuse.

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7. If fired without stemming.

8. If fired with combustible stemming.

9. If fired in the presence of a dangerous percentage of fire damp.

10. If the shot is a depending shot, is bored into the solid, or has a burden so heavy that the shot obviously is liable to blow out.

Many mines in Wyoming still use black blasting powder for blasting coal; also many mines in Wyoming do not rock-dust. Dust from the coals in Wyoming, tested by the United States Bureau of Mines, has been readily detonated in the Experimental mine by a blown-out shot of black blasting powder; therefore, unless the element of good luck continues to intervene, the stage is set for a dust explosion in such mines any time the necessary conditions arise.

CAUSES OF ACCUMULATIONS OF EXPLOSIVE ATMOSPHERES

Short-circuiting of air.- It is almost impossible to operate a mine without using some doors, but there is no reason why they should not be in pairs or supplemented with curtains. Doors should be self-closing, should be fireproofed, and should be constructed as nearly airtight as possible; they should not be equipped with latches to hold them open.

In case 4 the air presumably became short-circuited while men were fighting a mine fire. During the handling of a mine fire it is natural for all efforts to be concentrated upon extinguishing the fire; however, the person in charge should pay particular attention to the ventilation so that accumulations of gas will not occur where they can be moved around by the flame from the fire and ignited by it.

When old workings that give off quantities of methane gas are sealed the seals should be inspected regularly to see that they do not leak. A ventilating current should also be made to sweep the face of the seals in such a way as to prevent the accumulation of gas.

Two of the explosions listed under this heading were due to line brattices either being down or improperly installed so that enough air was not reaching the working face to keep it clear. Many mine officials and underground workers do not take the installation of line brattices seriously, especially in so-called nongassy mines. When properly installed with plenty of air available, line brattices are the best means of ventilating working places when advancing between crosscuts or breakthroughs. As there is leakage of air, even with the best-installed curtains and brattices, particular care should be taken by mine officials to see that they are installed to keep the leakage at a minimum.

Pocket of gas.- The inflammable gas commonly encountered in coal mines is known as methane, although there are mines in Wyoming that liberate gases

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nearly equivalent in composition to some of those given off by oil wells. These gases are of lighter specific gravity than air and unless diffused in the air currents will accumulate in high points in the roof; fire bosses or other persons examining the mine should take particular care to test high spots for accumulations of such gases. If gas accumulates at such points it can be removed by a brattice cloth installed at the roof or possibly by a pipe running from the high pocket directly into the return. When working places are driven to the rise in gassy mines officials should insist that the men keep the line brattice properly installed close to the face; also that crosscuts are driven at proper intervals and that there is enough air at the working place to keep it clear of gas.

Gases distilled by mine fires.- The explosibility of gases distilled by mine fires is illustrated by the explosions that often occur in coal stoves. In mines explosions due to mine fires often are very violent, with a large amount of inflammable gases and coal dust present. The mining system should be so designed that most possible fires can be readily sealed without danger to operation of the rest of the mine.

In addition to the hazard of an explosion from gases distilled by mine fires it must be remembered that such gases also contain rather high percentages of carbon monoxide, of which less than 0.5 of 1 percent can kill a man in a very few minutes.

Feeder opened by a shot.- In many coal mines it is impossible to tell when a shot may open a gas feeder; for this reason mines should be inspected after places have been shot and before the miners enter. The Wyoming law permits blasting of the coal at any time; the man that fires the shot, therefore, should carry a flame safety lamp and be competent to use it.

Gas from old workings.- In case 68, during the reopening of an old mine explosive gas from old workings leaked through a crevice in the coal; when old mines are reopened great care should be taken to examine the air, especially when old workings are approached, not only because of possibly encountering explosive gas but also from the hazard of black damp. Where the exact location of old workings is not known drill holes should be drilled ahead of the advancing workings and also to the sides; such drill holes should be deep enough so that when the coal is blasted there will be no danger that the shot will break into the old workings.

Dust raised by shots.- Improper location of drill holes, shooting off the solid, firing of dependent shots, use of too little or no stemming, and loading holes too heavily cause blown-out shots; these can be eliminated by proper supervision, assisted by safety education of miners and shot firers. If the shots are loaded and fired when the working shift is out of the mine the likelihood of wholesale fatalities from explosions caused by blown-out shots or from other causes in connection with the use or abuse of explosives in coal mines will be eliminated. In several mines in the United States all shots are fired from the outside of the mine while all the men are out of the

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mine. The explosives are taken into the mine by the shot firers after the shift is out of the mine; the shot firer loads and tamps all holes. If this practice is not feasible the next best method is to have a short firer load, tamp, and fire all the shot holes while all other persons are out of the mine.

As the law in Wyoming sanctions blasting the coal at any time during the shift, even in gassy mines, there is little likelihood that these methods will be used to any great extent in Wyoming mines. A good shot firer will not fire a charge placed in an improperly drilled hole, will not blast a place that is not properly undercut or sheared or where the "bug" dust is not removed from the cut, and will not overload a hole or tamp it with stemming containing coal dust. Therefore, the use of a shot firer to handle all explosives and to load and tamp all holes is probably the safest method possible with present practice in Wyoming. The United States Bureau of Mines, in Mine Safety Board Decision 2[4], recommends that for blasting in coal mines permissible explosives fired electrically be used exclusively and that as an aid to blasting all coal which is feasible to cut should be cut or sheared. The United States Bureau of Mines further, in its Mine Safety Board Decision 12[4], makes the following recommendation:

> The United States Bureau of Mines, extending Mine Safety Decision 2, recommends that for blasting either coal or rock in coal mines, permissible explosives or equivalent permissible device be used exclusively, and in addition recommends that in blasting -
>
> 1. Each charge shall be in a hole properly drilled and stemmed with incombustible material.
>
> 2. Each shot shall be fired separately by a permissible single-shot blasting unit, using an electric detonator or igniting equivalent of a kind specified by the Bureau for the particular permissible explosive or permissible blasting device.
>
> 3. Before and following each shot in gassy and slightly gassy coal mines, examination for gas shall be made with a permissible flame safety lamp or permissible equivalent and -
>
> 4. If more than 1½ percent of inflammable gas is found, in the quantity and by the method specified in Mine Safety Decision 9, the place shall be considered to be in a hazardous condition and before another shot is fired the gas shall be reduced by ventilation below the percentage and quantity specified in decision 9.
>
> 5. Each shot employing explosives shall be prepared and fired by or under the immediate supervision of a man having a state certificate as a mine examiner, fire boss, or foreman; and whenever conditions permit all other men than those authorized to prepare and fire shots shall be out of the mine when shot firing with explosives is being done.

4/ See footnote 3.

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Rock-dusting of all places to within a short distance of the working face and thorough wetting of the places from the end of the rock-dusted zone to and including the face before blasting will lessen the likelihood of occurrence of a coal-dust cloud.

Dust cloud raised by wrecked trip.- Coal-dust clouds raised by wrecked trips have caused the death of a number of men in the mines of Colorado and New Mexico. These explosions direct attention to the necessity for properly maintained and inspected haulage equipment and haulageways to prevent the occurrence of disasters of this type. As previously stated, the explosion listed as case 7 could have been prevented if a proper derail had been placed at the head of the slope. Sprinkling of trips, thorough rock-dusting of haulageways, rock-dust barriers, and keeping haulageways clean will tend to prevent the raising of dust clouds by a wreck or will localize the resulting explosion if a dust cloud is ignited.

Unknown.- Many if not most gas ignitions in coal mines are due to defective ventilation caused by improper installation of stoppings, doors, curtains, and line brattices and the use of doors in place of overcasts. The particular fault with the ventilation is not known for 52 of the mines in which the cause of the gas accumulations was not given in the reports available.

MEANS OF PREVENTING EXPLOSIONS AT THE TIME

Table 6 lists the means that would have prevented the explosions had they been in effect at the time.

TABLE 6.- Means of preventing explosion at time

Means of prevention	No. of explosions	No. killed	No. injured
Permissible flame safety lamp	1	99	
Permissible portable electric lights	2		2
Tight stoppings and better installation of line brattice	1	39	
Permissible mining machinery.	2	1	5
Sprinkling trip, derailing device	1	1	31
Better system of development.	1	0	
Better location of drill holes; permissible explosives	1	7	
Better inspection by fire boss	1	0	1
Positive ventilation	1	2	
Better care of ventilation	1	0	2
Unknown	56	382	62
Total	68	531	103

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Permissible flame safety lamps and permissible portable electric lamps.- The United States Bureau of Mines5/ makes the following decision relating to miners' lamps in coal mines:

1. In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also

2. In places where fire damp or black damp is liable to be encountered, a permissible, magnetically locked, flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in such place; and

3. Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and

4. All coal mines whether classed as nongassy or gassy in any part, be supplied with magnetically locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes.

The recommendations were made for the following reasons:

Open lamps or so-called safety lamps of unapproved kind may cause fires or ignite firedamp and coal-dust, and therefore they should not be used in coal mines. Miners' electric lamps have been so improved in illumination, convenience, and safety, that it is no longer to be considered a hardship in mining to use a portable permissible electric lamp, in fact it is quite the reverse.

However, since no approved electric lamp shows the presence of methane or indicates oxygen deficiency, one experienced employee in every place where such conditions are liable to be found should be provided with a permissible flame safety lamp, or equivalent permissible device to be used for testing.

Although a permissible flame safety lamp is safe if properly assembled and used, there is a possibility of its being a source of ignition of firedamp if the lamp is illegally opened in the mine or is dropped and the glass broken, or if the lamp is struck by a sharp point or is moved so rapidly as to cause flame to extend through the gauzes. Accordingly the use of the permissible flame safety lamp should be limited to gas testing in the hands of competent and experienced employees who can demonstrate with accuracy and safety the percentage of methane in the air in excess of 1½ or 2 percent. The flame safety lamp also gives information as to the sufficiency of oxygen in the surrounding atmosphere.

5/ Mine Safety Board Decision 1. See footnote 3.

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Other underground employees working or traveling in well-ventilated places should be provided with portable permissible electric lamps giving an excellent steady light; the good illumination which these lamps provide if maintained in proper condition tends to prevent accidents from falls and other hazards, and the equipment itself is free from the danger of igniting gas and coal dust.

Tight stoppings, better installation of line brattice.- Leaky stoppings between the air courses and other openings in many coal mines account for the greatest percentage of loss of ventilating current. The money lost from this leakage through excessive consumption of power at the fan may often more than pay for the inspection and repair of these stoppings. The proper installation of line brattice is necessary if mine officials and miners expect the proper ventilation at the working faces. The United States Bureau of Mines makes the following recommendation relating to the sealing of parts of mines which cannot be kept well ventilated and inspected.6/

In the interest of safety, the United States Bureau of Mines recommends that in coal mines all entries, rooms, panels, or sections that cannot be kept well ventilated throughout or cannot be inspected regularly and thoroughly or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

In the past the question of sealing has been a much disputed one among mining men. Some have considered that it was highly dangerous to inclose areas in a mine which might fill with a body of gas. The Bureau agrees with this point of view, unless the stoppings are strong and fireproof; and by strength is meant sufficient to maintain the stoppings in place if there should be a heavy fall of roof in an empty or partly empty goaf, suddenly compressing the gas or a gas-air mixture.

On the other hand, engineers of the Bureau find from extensive experience that in large room-and-pillar mines in which the pillars are either not extracted at all or not extracted for a long period, the old areas are not generally well-ventilated and often cannot be inspected because of danger of falls, and that the lack of ventilation is inevitable from the enormous territory which may be opened. Furthermore, these regions act as places for accumulating dangerous dust as well as gas.

The Bureau believes that the ideal system of room-and-pillar coal mining is to take out only a small percentage of coal on the advance, generally less than 20 percent, and then to extract the pillars promptly on a systematic line of retreat for the whole mine or for a large panel, which may be considered equivalent to longwall retreating. Under such conditions there should be no need of sealing extensive areas of open unused workings when they can be properly ventilated.

6/ Mine Safety Board Decision 6. See footnote 3.

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Where the workings of a mine, whether it is a metal or coal mine, have been connected to an adjacent mine and after more or less extraction of the mineral in that part of the mine, the connecting workings are not tightly closed, strong fireproof doors or stoppings should be erected in such connections at or near the boundary of the mine. The objective of this is to prevent fire or fumes entering from one mine to the other. In the case of coal-mine workings which have been connected, these stoppings should not only be fireproof but should be strong enough to resist the pressure of a gas or dust explosion. Explosion tests by the Bureau of Mines on the strength of stoppings indicate that a plain concrete slab acting as a flat arch when properly keyed into the ribs and floor, probably is the most practicable form of construction for a fireproof stopping strong enough to resist an explosion of ordinary degree of violence.

In erection of barrier-pillar stoppings which subsequently may be subjected to high hydraulic pressure through abandonment of the adjacent mine workings and their filling with water, a release to avoid high-water pressure should be provided. This might be an inclined pipe extending down into a water-filled sump on the inby side of the stopping, thus furnishing a water seal to prevent escape of gas into workings in active operation.

Permissible mining machinery.- Permissible coal-mining machinery is available for nearly every operation in or about a coal mine, and the Bureau of Mines recommends[7] that in gassy mines electrical equipment shall be permissible.

Sprinkling trip and derailing device.- In many coal mines all loaded trips are sprinkled at the sectional parting and at the main parting. In some mines trips of empty cars are sprinkled before they are allowed to enter the mine. Wetting the coal on a trip or wetting the empty cars assists in preventing the raising of a dust cloud if the trip should be wrecked and prevents the dust from blowing off the trip and settling on ribs, roof, timbers, and road, thus reducing the dust hazard and the necessity of frequent redusting along haulageways.

Better system of development.- Many of the mine explosions and mine fires can be placed under this heading. In general, coal mines should be so developed that if a fire occurs at any point there will be a barrier pillar between it and other workings with a minimum amount of openings so the fire can be completely sealed without excessive danger to the workmen.

Permissible explosives and better location of holes.- As previously stated, the Bureau of Mines recommends the use of permissible explosives only or of equivalent permissible blasting devices. The proper location of drill holes depends much upon the local conditions with respect to the coal bed and it is often difficult to educate the miner to place the holes properly.

7/ Mine Safety Board Decision 13. See footnote 3.

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Better ventilation.- Proper ventilation should be given first consideration in the operation or development of any coal mine; rock-dusting and other safety devices are secondary to ventilation.

EXPLOSIBILITY OF WYOMING COAL DUST

The United States Bureau of Mines tests show that semianthracite, bituminous, and subbituminous coal dust is explosive under certain conditions. Experiments by the Bureau of Mines have proved that the ratio of the percentage of volatile matter to volatile matter plus the fixed carbon in the coal, other factors being equal, is an index of the explosibility of coal dust, the higher the volatile matter generally the more explosive the dust. Any coal dust which has this ratio greater than 0.15 is explosive in the absence of gas. The presence of any considerable quantity of inflammable gas in the mine air increases this explosibility of the dust; therefore, an additional quantity of rock-dust should be added to the ribs, roof, floor, timbers, and "caves" in coal mines to neutralize the effect of the gas present. The dust of all Wyoming coals tested at the experimental mine of the United States Bureau of Mines has been found to be explosive; undoubtedly no mine in Wyoming can be considered safe from a dust explosion unless all underground surfaces are thoroughly wet or rock-dusted from the working faces to the mine opening.

CONCLUSIONS

The record of explosions in Wyoming compared to that of neighboring States is relatively good, but Wyoming has had some disastrous explosions and a number of gas ignitions which, although resulting in injury to only one or two men, might have constituted the beginning of disastrous explosions. Many mines still do not use rock-dust or permissible explosives; measures should be taken in all Wyoming coal mines to minimize the possibility of a general explosion by maintaining good ventilation and effective rock-dusting and by using permissible explosives.

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